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ALGAL STUDIES IN BOLIVIA: A COMPILATION AND PRELIMINARY ANALYSIS OF EXISTING PHYCOLOGICAL LITERATURE

ESTUDIOS ALGALES EN BOLIVIA: UNA COMPILACION Y ANALISIS PRELIMINAR DE LA LITERATURA FICOLOGICA EXISTENTE

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ABSTRACT

A compilation of phycological literature published on Bolivian algae is presented together with an analysis of strengths, weaknesses, and needs in this field of investigation. An analysis of the nationality of authors, type, content, and geographic focus of the references shows that literature is largely produced by foreign scientist, concentrated on just a few areas of the country, or are biased toward particular algal groups, leaving ample room for more exploration. The Altiplano (high mountain plateau) and Amazon concentrate most of the publications, the phytoplankton and algae found in sediment cores, being the communities that have received more attention from scientists. Taxonomic references focus more on phytoplankton and tychoplankton communities and are largely restricted to the mere presentation of taxa lists, but using old and geographically unsuitable floras as the source for taxa names. The present work does not incorporate an account of the number and identity of taxa at the genus, species or infraspecific levels. That work will be presented later after appropriate taxonomic review. The purpose of this compilation is to provide an overview for what is known about Bolivian algae up to this point and to provide the bases for further investigations in this field, including a catalog of Bolivian algae.

KEYWORDS: Bolivia, phycology, algae, freshwater.

RESUMEN

Se presenta una compilación de la literatura sobre algas de Bolivia junto con un análisis de las fortalezas, debilidades y necesidades en este campo de investigación. Un análisis de la nacionalidad de los autores y tipo, contenido y distribución geográfica de las referencias bibliográficas muestra que la literatura ha sido producida en su mayoría por investigadores extranjeros y que está concentrada en gran medida en sólo algunas áreas del país o que posee un sesgo hacia ciertos grupos algales, dejando un amplio espacio para exploraciones adicionales. El altiplano (meseta de alta montaña) y la parte amazónica concentran la mayor parte de las publicaciones, con el fitoplancton y algas en testigos de sedimentos como las comunidades que han recibido una mayor atención por parte de los científicos. Las referencias taxonómicas se centran más en las comunidades del fitoplancton y metafiton y se restringen de sobremanera a la presentación de meras listas taxonómicas basadas en floras antiguas y geográficamente inapropiadas como fuentes de nombres científicos. El presente trabajo no incorpora un recuento del número e identidad de los taxa a nivel de género, especie o niveles infraespecíficos. Ese trabajo se presentará después de una revisión taxonómica apropiada. El propósito de la presente compilación es el de proveer una visión general de lo que se conoce hasta el momento acerca de las algas bolivianas y proveer las bases para investigaciones adicionales en este campo, incluyendo un catálogo de algas bolivianas.

PALABRAS CLAVES: Bolivia, ficología, algas, aguas continentales.

INTRODUCTION

Bolivia is a small, but extremely biodiverse country, being among the 20 countries with most biodiversity on the planet (Ibisch & Mérida 2003). The reason for such a great diversity is the varied landscape, including mainly high mountain plateaus (Altiplano), sub Andean dry forest, cloud forest (Yungas), Amazon-influenced lowlands, and the Chaco formation, all of which are also characterized by diverse climatic conditions (Navarro & Maldonado 2004).

Interest in Bolivian biodiversity is relatively recent and much of the work has been produced only within the last 20 years. Insects, aquatic and terrestrial vertebrates, and higher plants have received more attention, while there are only a fewer studies on crustaceans, lower plants and the algae. Published works are extremely difficult to find due to lack of specialized libraries and to the fact that a great proportion of biological research is done outside the country and published in journals that have restricted circulation in Bolivia. Recently, summaries and some electronic files of a limited number of works have become available, yet this represents only a small part of the total number of articles and books published on the algae from Bolivia. A portion of the existing literature can be found in libraries belonging to herbaria or to universities offering careers related to the biological sciences. Even the more general manuscripts produced in or outside the country circulate among a very small group of scientist and there is certainly very little effort directed toward making this literature available to students and the public in general.

In the case of phycological literature, its circulation is even more restricted and there is not a single collection containing even half of the total existing literature, which severely hinders further scientific progress and/or formation/education of professionals in the area. The lack of interest in the algae is deepened by a lack of specialized courses or graduate and undergraduate programs in universities directed to teaching algae. Paradoxically, in its position as a third world country and with a severely uncontrolled population growth, applied phycological research such as algae as bioindicators, is considerably underdeveloped in Bolivia.

The present work compiles as many phycological references as possible on Bolivian algae published both inside and outside Bolivia. The purpose of this compilation is to provide an overview for what is known about Bolivian algae thus far and to provide the bases for further investigations in this field.

MATERIALS AND METHODS

Several sources were used to search for published literature. These included electronic queries through the Academy of Natural Sciences of Philadelphia (ANSP) library, which yielded a great number of references and abstracts of material published mainly in North America and Europe. Several queries were also done through the internet using key words related to “Bolivia”, “algae”, particular algal groups, or combinations of these key words. These also yielded references published throughout the world in the form of books, articles and theses, and several electronic files that were downloaded for inspection. In Bolivia, private collections of colleagues working or having worked with algae where thoroughly searched for algal publications. Also, the specialized library at Unidad de Limnología y Recursos Acuáticos (ULRA), Universidad Mayor de San Simón (UMSS) in the city of Cochabamba provided additional references. In the case of private collections and the ULRA library, they yielded investigation reports and undergraduate and master’s theses that are not commonly published/found outside the academic environment. These were inspected directly.

All references were categorized on “subject”, “geographic area”, “algal division/phylum” and “type of algal community” based on the format used by Marticorena (1992, 1996). Contents were assessed based on titles (in the case of references for which a copy/electronic file could not be found) or direct review of the material. A separate analysis for references dealing with taxonomic issues was made considering their geographic coverage and algal group studied. Taxonomic categories reported in this text are taken directly from the references encountered (e.g. Cyanophyta, Xanthophyta, Chrysophyta, etc.), and no attempt is made to find their current taxonomic equivalency. This latter work will be presented together with the catalogue of Bolivian algae.

Results are shown in a list and graphs elaborated using Microsoft EXCEL and based on the above categorization. References belonging to a category are reported in the text as a percentage of the total number of references, followed by the actual number of references in parentheses.

RESULTS AND DISCUSSION

A categorization of all found literature is presented at the end of the article. this categorization is to be used in conjunction with the Bibliography list presented here. A single article can belong more than one category following the categorization criterion.

A total of 157 references were found (Fig. 1A), 67% (106) of which correspond to peer reviewed articles in journals throughout the world. Chapters, part of edited books, amounted to 12% (19) of the references, while 9% (14) were books entirely devoted to the algae. Theses and technical reports were found in lower numbers, 8% (12) and 4% (6), respectively.

One hundred and fifty eight references, for a country with such diverse ecosystems, represents a low number, unrepresentative of the potential flora, and reflective of a severe lack of studies in the area of phycology and related applied branches. In addition to these problems, there is an evident lack of interest on the algae from native researchers. Publications authored by foreign scientists amount to 69%, while references authored by Bolivian researchers amount to only 21.5%. Publications authored by joint collaborations represent 9.5% of the total of publications. The majority of publications produced by foreigners are the result of expeditions or international cooperation such as ORSTOM (Office de la Recherche Scientifique et Technique d'Outre-Mer, now IRD, Institut de Recherche pour le Développement). Interestingly, phycological research in Bolivia has been relatively steady since the first publication (Montagne 1839). Up until 1990, 47.5% (75) of the publications had been produced and 52.5% (82) were published after that date.

Although, ecology and taxonomy are the primary focus of this literature (56 and 54 references, representing 36% and 34%, respectively) (Fig. 1B), there is a clear bias in the geographic interest of researchers. Figure 1C shows that 61% (96) of all references concentrate only on the Altiplano region, while references for other areas amounted to 15% or less. It is worth noting that the geographic areas in Figure 1C are those found represented in the surveyed literature, but not all the bioclimatic regions of the country.

Palaeoecological and earth sciences-related publications form part of the next largest set of publications (20%, 32 references) grouped by field of coverage (Fig. 1B). General references, covering topics such as new techniques, non-scientific informative articles, and essays amount to 6% (10), while fossil floras and chemistry articles represent 3% (4) and 1% (1), respectively. Palaeoecological references are entirely restricted to the altiplano, as well as fossil floras, but they are concentrated on a small number of ecosystems that are unrepresentative of this region since they focus on large extinct and extant lakes and rivers.

Geographically, the Amazon has received more attention after the Altiplano, with 15% (23) of the publications (Fig. 1C). Yet, also in this case, the publications are largely unrepresentative of the region and concentrated on a few lakes and oxbow ecosystems, and there is very little work done on the large rivers that dominate the landscape in this area of the country. Publications on algae from the high valleys and the yungas represent 8% (13) and 4% (6), respectively. These two areas, especially the yungas have a tremendous potential for biodiversity and related studies. Morales & Vis (2007) reported that more than 20% (of 172 taxa at the species and variety levels) of the diatom taxa they found in three streams from the yungas of La Paz, were not found in published floras from different parts the world. A previous article (McClintic *et al.* 2003), had highlighted a similar case for the algae without hard cellular components. Ten references (6%) correspond to works in which algae are treated in a general sense without mention of geographic regions. Four of the references treated all geographic areas at the same time (3%), while 5 references treated algae from territories no longer part of Bolivia (3%).

In order to determine which community of algae has received more attention from scientists, all pertinent literature was examined either by title or by reading the contents, yielding 116 references (Fig. 1D). Publications on phytoplankton by far dominate this set: 45% (52). Yet, many of the phytoplankton studies that were examined for contents often listed periphyton taxa, as well. This suggests that many of these references intended to deal with phytoplanktic algae, actually deal with a tychoplanktic mixture.

The next largest set among the references arranged by studied community is that of algae found in sediments and often collected as sediment cores from extant and extinct lakes and rivers (28%, 33 references). Most of these studies are palaeoecological in nature and are largely restricted to the Altiplano. References dealing with all algal communities ("mixed") at the same time or dealing with algae in general were 15% (17) of the total, while references dealing with lentic

tychoplankton amounted to 3% (4). The latter community has been studied mainly from the taxonomic point of view, with little work done on its ecology or other aspects. Since the tychoplankton represents a chaotic mixture of algae from different communities within an ecosystem, these references probably serve as mere taxonomic lists, with use for biodiversity and cataloguing studies, although a taxonomic review of the taxa determinations is still pending.

Interestingly, the periphyton references only amount to 9% (10) of the total. Since the periphyton arguably contains the greatest diversity among all algal communities developing in continental waters, it can be stated that very little is known about Bolivian periphytic algae in particular and about all Bolivian algae in general.

Particular attention was devoted to the taxonomic references gathered in this survey. Taxonomy results are fundamental for further progress in other branches of phycological research, especially in applied areas such as bioindication. It is of course, of prime importance that the taxonomy presented in a group of references is compatible and that the taxonomic work is properly supported by graphic material or material deposited in herbaria.

As reported above, 34% of all references dealt with algal taxonomy issues. These are mostly reports of algae from given ecosystems located in particular regions of the country (Fig. 1E). The Altiplano received most of the attention from this point of view, as well (35%, 19 references), while taxonomic references for the Amazon amounted to 28% (15) of the references. The high valleys and the yungas have received similar coverage with 13% (7) and 11% (6), respectively. Two of the references cover more than one region of the country at the same time (4% of all taxonomic literature), although, they are also more general in their treatment of the algae and provide (incomplete) taxa lists. Five of the taxonomic references (9%) treated the algae of regions that are not part of the current Bolivian territory.

There are no studies concentrated on biogeographic areas that are of importance in the Bolivian and South American context, such as the Chaco region in the southeast, the Cerrado and Pantanal areas in the east and northeast. The Tucumano-Boliviano formation in the south, a southern limit of the cloud forest referred above as yungas, has not been explored either.

The higher elevations of the two Andean branches entering the country have also been little studied and there are entire areas of this region that have not been explored at all from the biological standpoint. It is common that during field trips, Andean lotic ecosystems above 4.200 m a.s.l. contain higher densities of algae and macroinvertebrates than streams at lower elevations (M. Maldonado, pers. comm.), but this biodiversity and the reasons for their abundance are yet to be known.

An analysis of the algal groups (at the level of Division/Phylum) covered by the taxonomic references was also performed (Fig. 1F). General floras including several groups are by far the largest set 52%, 28 references). The diatoms are the single division that has been studied the most (22%, 12), followed by the Chlorophyta (15%, 8), Euglenophyta (7%, 4), and the Xanthophyta and Dinophyta (2%, 1 reference each). Algal groups such as the Cyanophyta, Chrysophyta, Cryptophyta, etc, are only listed in the "general floras" category and have not been studied in any depth. Also, for the great majority of the divisions that have been studied singly, the taxonomic treatment is not rigorous and the majority of taxa have been identified using old floras (as evidenced by the Division names used above) or references dealing with European floras that are certainly different from those present in the southern hemisphere. A great number of taxa reported in these references must be updated/re-identified based on recent advances in taxonomy and systematics.

CONCLUSIONS

Bolivian phycological literature is limited and does not cover the wide range of ecosystems characteristic of the Bolivian territory. The phytoplankton/tychoplankton from the Altiplano and Amazon has been studied the most, but the literature remains largely taxonomic. However, this taxonomy is not deep and only covers a reduced number of groups, of which the diatoms concentrate the largest number of references.

The lack of interest on Bolivian algae severely hinders the development of applied fields such as bioindication, biotechnology, and others, which might represent viable solutions to Bolivia's current economic condition. Also, the biodiversity of this group of organisms remains unknown, which is paradoxical in a country that has been considered as being among the 20 countries with highest diversity on the planet.

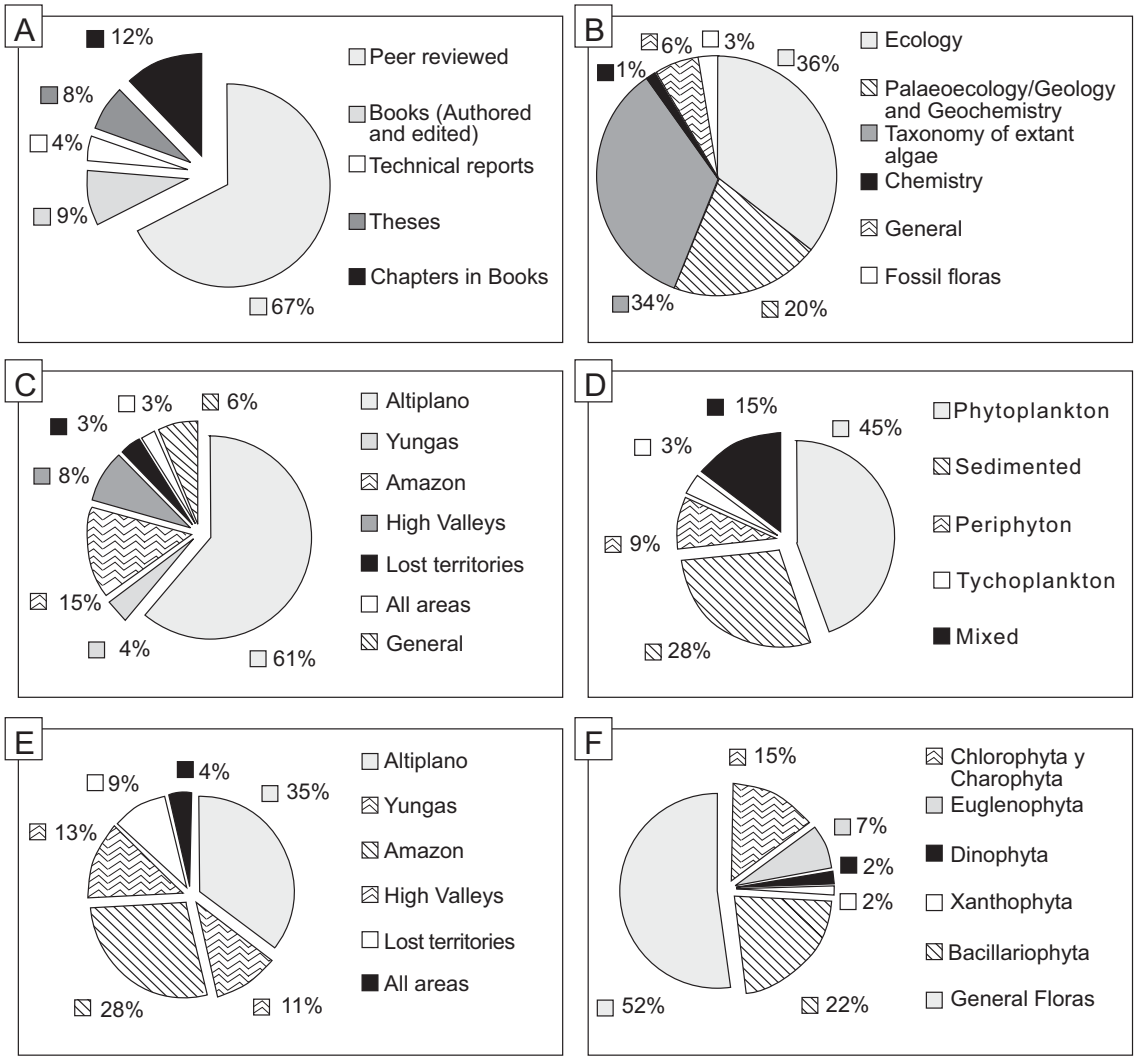

FIGURE 1. Pie charts showing the different categorizations of the Bolivian phycological literature. A. Categorization based on type of text for all 157 references. B. Categorization of all references based on subject covered. C. Categorization of all references based on geographic area covered. D. Categorization based on type of algal community studied, for all pertinent references (116 references). E. Categorization based on geographic area covered for taxonomic literature only (54 references). F. Categorization based on algal division/phylum treated, for taxonomic literature only.

FIGURA 1. Diagramas de torta mostrando las diferentes categorizaciones de la literatura ficológica boliviana. A. Categorización basada en el tipo de texto para las 157 referencias compiladas. B. Categorización de todas las referencias basada en el tópico del artículo. C. Categorización de todas las referencias basada en el área geográfica cubierta. D. Categorización basada en el tipo de comunidad algal estudiada basada en las referencias pertinentes al tópico (116 referencias). E. Categorización basada en el área geográfica cubierta, sólo para referencias taxonómicas (54 referencias). F. Categorización basada en la División/Phylum algal, sólo para las referencias taxonómicas.

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Vincent, W.F., W. Wurtsbaugh, C.L. Vincent & P.J. Richerson. 1984. Seasonal dynamics of nutrient limitation in a tropical high altitude lake (Lake Titicaca, Peru-Bolivia) application of physiological bioassays. Limnology and Oceanography 29: 540-552.

Widmer, C., T. Kittel & P.J. Richerson. 1975. A survey of the biological limnology of Lake Titicaca. Internationale Vereinigung für theoretische und angewandte Limnologie. Verhandlungen 19: 1504-1510.

Wurtsbaugh, W.A., W.F. Vincent, R.T. Alfaro, C.L. Vincent & P.J. Richerson. 1985. Nutrient limitation of algal growth and nitrogen fixation in a tropical alpine lake, Lake Titicaca (Peru, Bolivia). Freshwater Biology 15: 185-195.

Wurtsbaugh, W.A., W.F. Vincent, C.L. Vincent, H.J. Carney, P.J. Richerson, X. Lazzaro & R.T. Alfaro. 1991. Nutrientes y su limitación del crecimiento del fitoplancton. En: El lago Titicaca: Síntesis del conocimiento actual (eds. C. Dejoux & A. Iltis), pp. 161-170. ORSTOM, Talleres gráficos Hisbol. La Paz, Bolivia.

Wurtsbaugh, W.A., W.F. Vincent, C.L. Vincent, H.J. Carney, P.J. Richerson, X. Lazzaro & R.T. Alfaro. 1992. Nutrient limitation of phytoplankton growth in Lake Titicaca. In: Lake Titicaca, synthesis of limnological knowledge (eds. C. Dejoux & A. Iltis), pp. 147-160. Kluwer Academic Press, The Netherlands.

Ybert, J.P. 1992. Ancient lake environments as deduced from pollen analysis. In: Lake Titicaca: A synthesis of limnological knowledge, Monographiae Biologicae, vol. 68. (eds. C. Dejoux & A. Iltis), pp. 49-62. Kluwer Academic Publishers. Dordrecht, The Netherlands.

Categorization of Bolivian phycological literature. This information is to be used with the list presented under Bibliography above. Categorization was based on title and/or content of the publications.

Categorización de la literatura ficológica boliviana. Esta información se debe utilizar junto con la lista provista en la Bibliografía presentada anteriormente. La categorización se hizo sobre la base del título o contenido de las publicaciones.

1. Categorization on subject

Chemistry

Achitouv, E., P. *et al.* 2004.

Ecology

Acosta, F. 2005.
Acosta, F. & R. Ayala 2003.
Acosta, F. *et al.* 2003.
Ayala, R. 2002.
Ayala, R. *et al.* 2003.
Barra, C. *et al.* 1990, 1993.
Cabrol, N.A. *et al.* 2004.
Cadima, F.M. 1996, 1998, 1999.
Cadima, F.M. & E.A. Morales 1989-92, 1991.
Cadima, F.M. *et al.* 1991, 2000.
Carney, H.J. 1984.
Carney, H.J. *et al.* 1987, 2004.
Castro, M.M. 2002.
Colque, J.M. 2003.
Dalence, S. 1998.
Dejoux, C. & A. Iltis 1992.

Fontúrbel, R.F. 2003, 2005a, 2005b, 2006
Gutiérrez, M. & F.M. Cadima 2004.
Iltis, A. 1991b, 1993.
Iltis, A. *et al* . 1984, 1990.
Justiniano, M.A. 1999.
Lazzaro, X. 1981, 1985.
Liberman, M. & C. Miranda 1987.
Maldonado, M. *et al.* 1996.
Mendoza, C. *et al*. 2002.
Miskane, N. 1992.
Morales, E. A. 1993.
Morales, E.A. & F.R. Trainor 1996.
Pouilly, M. *et al*. 1999, 2004.
Rejas, D. *et al.* 2005.
Richerson, P.J. & H.J. Carney 1988.
Richerson, P.J. *et al*. 1977, 1991, 1992.
Rocha, O. 2002.
Servant-Vildary, S. 1982.
Vincent, W.F. *et al*. 1984,1985, 1986.
Widmer, C. *et al.* 1975.
Wurtsbaugh, W.A. *et al.* 1985, 1991, 1992.

FOSSIL FLORAS
Frenguelli, J. 1929.
Pierre, J-F. 1990.
Servant-Vildary, S. 1978a.
Servant-Vildary, S. & M. Blanco 1984.

PALEOECOLOGY, GEOLOGY Y GEOCHEMISTRY
Badaut, D. 1981.
Badaut, D. & F. Risacher 1983.
Badaut, D. *et al.* 1979.
Baker, P.A. *et al.* 2003.
Edwards, D. *et al.* 2001.
Focault, A. 1987.
Fröhlich, F. & S. Servant-Vildary 1989
Harikawa, K. *et al.* 1982.
Jones, B. & R.W. Renaut 1994.
Miskane, N. 1997.
Mourguiart, P. 1999.
Mourguiart, P. & M-P. Ledru 2003a, 2003b.
Pierre, J-F. 1987.
Pierre, J-F. & D. Wirrmann 1986.
Rigsby, C.A. *et al.* 2005.
Roux, M. *et al.* 1991.
Seltzer, G.O. *et al.* 2002.
Servant, M. *et al.* 1995.
Servant-Vildary, S. & M. Roux 1990a,1990b.
Servant-Vildary, S. & S.H. Mello e Souza 1993.
Servant-Vildary, S. *et al*. 2001.
Sylvestre, F.M. 1997, 2002.
Sylvestre, F.M. *et al.* 1996, 1998, 1999a, 1999b, 2001.
Tapia, P.M. *et al.* 2003.
Ybert, J.P. 1992.

TAXONOMY OF EXTANT ALGAE
Allen, G.O. 1940.
Borge, O. 1906.
Britton, E.G. 1896.
Cadima, F.M. 1986, 1988, 1990, 1992, 1993.
Cadima, F.M. & E.A. Morales 1992, 1994.
Cadima, F.M. *et al*. 1994.
Couté, A. & A. Iltis 1988
Couté, A. & Y. Thérézien 1985, 1994.
Ehrenberg, C.G. 1854a, 1854b.
Fernández, C.S. 2002.
Frenguelli, J. 1939, 1940.
García, E. & S.G. Beck 2006.
Guerlesquin, M. 1981a, 1981b.
Gutiérrez, V.M. 1999.
Horn Af Rantzien, H. 1950.
Iltis, A. 1984, 1991a.
Iltis, A. & A. Couté 1984.
McClintic, A.S. *et al*. 2003.
Montagne, C. 1839.
Morales, E.A. & M.L. Vis 2007.
Patrick, R. 1961.
Reyssac, J. & N.T. Dao 1977.
Roux, M. *et al.* 1987.
Servant-Vildary, S. 1978b, 1983a, 1983b, 1984, 1986, 1992.
Tell, G. 1998.
Tempere J., & H. Peragallo 1889-95, 1907-15.
Thérézien, Y. 1985, 1986a, 1986b, 1987, 1989, 1991, 1994.
Theriot, E. *et al*. 1985.
Tutin, T.G. 1940.
Vajda-Santivanez, V. 1999.
Villafañe *et al*. 1992.
Villarte, F. 1994.

GENERAL
Cadima, F.M. 1994, 2001.
Cadima, F.M. *et al.* 2006.
Dejoux, C. & A. Iltis 1991.
Gaylarde, P.M. & C.C. Gaylarde 2000.
Iltis, A. 1991c.
López, L.F. 2003.
Morales, E.A. 2006.
Morales, E.A. & F.R. Trainor 2001.
Navarro, G. & M. Maldonado 2004.

2. CATEGORIZATION ON GEOGRAPHIC AREA

ALTIPLANO

Allen, G.O. 1940.
Badaut, D. 1981.
Badaut, D. & F. Risacher 1983
Badaut, D. *et al.* 1979.
Britton, E.G. 1896.
Cabrol, N.A. *et al.* 2004.
Cadima, F.M. 1988, 1992, 1994.

Carney, H.J. 1984.
Carney, H.J. *et al*. 1987, 2004.
Couté, A. & A. Iltis 1988
Dejoux, C. & A. Iltis 1991, 1992.
Edwards, D. *et al*. 2001.
Fontúrbel, R.F. 2003, 2005a, 2005b, 2006.
Focault, A. 1987.
Frenguelli, J. 1929, 1939, 1940.
Fröhlich, F. & S. Servant-Vildary 1989
García, E. & S.G. Beck 2006.
Guerlesquin, M. 1981a, 1981b.
Harikawa, K. *et al.* 1982.
Horn Af Rantzien, H. 1950.
Iltis, A. 1984, 1991a, 1991b, 1991c, 1993.
Iltis, A. & A. Couté 1984.
Iltis, A. *et al* . 1984, 1990.
Jones, B. & R.W. Renaut 1994.
Lazzaro, X. 1981,1985.
Liberman, M. & C. Miranda 1987.
Mendoza, C. *et al*. 2002.
Miskane, N. 1992, 1997.
Mourguiart, P. 1999.
Mourguiart, P. & M-P. Ledru 2003a, 2003b.
Patrick, R. 1961.
Pierre, J-F. 1987, 1990.
Pierre, J-F. & D. Wirrmann 1986.
Reyssac, J. & N.T. Dao 1977.
Richerson, P.J. & H.J. Carney 1988.
Richerson, P.J. *et al*. 1977, 1991, 1992.
Rigsby, C.A. *et al*. 2005.
Rocha, O. 2002.
Roux, M. *et al.* 1987, 1991.
Seltzer, G.O. *et al.* 2002.
Servant, M. *et al.* 1995.
Servant-Vildary, S. 1978a, 1978b, 1983a, 1983b, 1983b, 1986, 1992.
Servant-Vildary, S. & M. Blanco 1984.
Servant-Vildary, S. & M. Roux 1990a, 1990b.
Servant-Vildary, S. & S.H. Mello e Souza 1993.
Servant-Vildary, S. *et al*. 2001.
Sylvestre, F.M. 1997, 2002.
Sylvestre, F.M. *et al.* 1996, 1998, 1999a, 1999b, 2001.
Tapia, P.M. *et al.* 2003.
Theriot, E. *et al.* 1985.
Tutin, T.G. 1940.
Vajda-Santivanez, V. 1999.
Villafañe *et al*. 1992.
Villarte, F. 1994.
Vincent, W.F. *et al.* 1984, 1985, 1986.
Widmer, C. *et al.* 1975.
Wurtsbaugh, W.A. *et al.* 1985, 1991, 1992.
Ybert, J.P. 1992.

AMAZON
Ayala, R. 2002
Ayala, R. *et al.* 2003.
Cadima, F.M. 1986, 1990, 1996.
Cadima, F.M. & E.A. Morales 1994.
Couté, A. & Y. Thérézien 1985, 1994.
Dalence, S. 1998.
Gutiérrez, V.M. 1999.
Gutiérrez, M. & F.M. Cadima 2004.
Justiniano, M.A. 1999.
Maldonado, M. *et al*. 1996.
Pouilly, M. *et al.* 1999, 2004.
Rejas, D. *et al.* 2005.
Tell, G. 1998.
Thérézien, Y. 1985, 1986a, 1986b, 1987,1989,1994.

HIGH VALLEYS
Acosta, F. 2005.
Acosta, F. & R. Ayala 2003.
Barra, C. *et al*. 1993
Borge, O. 1906.
Cadima, F.M. 1998.
Cadima, F.M. & E.A. Morales 1989-92, 1992.
Cadima, F.M. *et al.* 2000.
Castro, M.M. 2002.
Colque, J.M. 2003.
Gaylarde, P.M. & C.C. Gaylarde 2000.
Morales, E.A. 1993.
Morales, E.A. & F.R. Trainor 1996.

YUNGAS
Baker, P.A. *et al.* 2003.
Cadima, F.M. 1993.
Cadima, F.M. *et al*. 1994.
McClintic, A.S. *et al.* 2003.
Morales, E.A. & M.L. Vis 2007.
Thérézien, Y. 1991.

LOST TERRITORIES
Ehrenberg, C.G. 1854a, 1854b.
Montagne, C. 1839.
Tempere, J. & H. Peragallo 1889-95, 1907-15.

ALL AREAS
Acosta, F. *et al.* 2003.
Cadima, F.M. *et al.* 1991, 2006.
Navarro, G. & M. Maldonado 2004.

GENERAL
Achitouv, E. P. *et al.* 2004.
Barra, C. *et al*. 1990.
Cadima, F.M. 1999, 2001.
Cadima, F.M. & E.A. Morales 1991.
Fernández, C.S. 2002.
López, L.F. 2003.
Morales, E.A. 2006.
Morales, E.A. & F.R. Trainor 2001.
Servant-Vildary, S. 1982.

3. CATEGORIZATION ON ALGAL DIVISION/PHYLUM

BACILLARIOPHYTA

Baker, P.A. *et al.* 2003.
Frenguelli, J. 1929, 1939, 1940.
Fröhlich, F. & S. Servant-Vildary 1989
Miskane, N. 1992,1997.
Morales, E.A. & M.L. Vis 2007.
Patrick, R. 1961.
Pierre, J-F. 1987, 1990.
Pierre, J-F. & D. Wirrmann 1986.
Rigsby, C.A. *et al.* 2005.
Roux, M. *et al.* 1987, 1991.
Seltzer, G.O. *et al.* 2002.
Servant, M. *et al.* 1995.
Servant-Vildary, S. 1978a, 1978b, 1982, 1983a, 1983b, 1984, 1986, 1992.
Servant-Vildary, S. & M. Blanco 1984.
Servant-Vildary, S. & M. Roux 1990a, 1990b.
Servant-Vildary, S. & S.H. Mello e Souza 1993.
Servant-Vildary, S. *et al.* 2001.
Sylvestre, F.M. 1997, 2002.
Sylvestre, F.M. *et al.* 1996, 1998, 1999a, 1999b, 2001.
Tapia, P.M. *et al.* 2003.
Tempére J. & H. Peragallo 1889-95, 1907-15.
Theriot, E. *et al.* 1985.

CHLOROPHYTA & CHAROPHYTA

Allen, G.O. 1940.
Couté, A. & A. Iltis 1988.
Guerlesquin, M. 1981a, 1981b.
Horn Af Rantzien, H. 1950.
Thérézien, Y. 1985, 1986a, 1986b.

EUGLENOPHYTA

Couté, A. & Y. Thérézien 1985, 1994.
Fontúrbel, R.F. 2006.
Tell, G. 1998.
Thérézien, Y. 1994.

DINOPHYTA

Iltis, A. & A. Coute 1984.

XANTHOPHYTA

Therezien, Y. 1987.

GENERAL FLORAS

Acosta, F. 2005.
Acosta, F. & R. Ayala 2003.
Acosta, F. *et al.* 2003.
Barra, C. *et al.* 1990, 1993.
Borge, O. 1906.
Britton, E.G. 1896.
Cadima, F.M. 1986, 1988, 1990, 1992, 1993, 1996, 1998.
Cadima, F.M. & E.A. Morales 1989-92, 1992, 1994.
Cadima, F.M. *et al.* 1994, 2000, 2006.
Carney, H.J. *et al.* 1987.
Castro, M.M. 2002.
Colque, J.M. 2003.
Dalence, S. 1998.
Dejoux, C. & A. Iltis 1992.
Edwards, D. *et al.* 2001.
Ehrenberg, C.G. 1854a, 1854b.
García, E. & S.G. Beck 2006.
Gaylarde, P.M. & C.C. Gaylarde 2000.
Gutiérrez, V.M. 1999.
Gutiérrez, M. & F.M. Cadima 2004.
Harikawa, K. *et al.* 1982.
Iltis, A. 1984, 1991a, 1991b, 1991c.
Iltis, A. *et al* . 1984, 1990.
Justiniano, M.A. 1999.
Lazzaro, X. 1981, 1985.
Liberman, M. & C. Miranda 1987.
López, L.F. 2003.
Maldonado, M. *et al.* 1996.
McClintic, A.S. *et al.* 2003.
Montagne, C. 1839.
Morales, E.A. 1993.
Morales, E.A. & F.R. Trainor 1996.
Navarro, G. & M. Maldonado 2004.
Pouilly, M. *et al.* 2004.
Reyssac, J. & N.T. Dao 1977.
Richerson, P.J. & H.J. Carney 1988.
Richerson, P.J. *et al.* 1977.
Thérézien, Y. 1989, 1991.
Tutin, T.G. 1940.
Vajda-Santivanez, V. 1999.
Villafañe *et al.* 1992.
Widmer, C. *et al.* 1975.

4. CATEGORIZATION ON TYPE OF ALGAL COMMUNITY

PERIPHYTON

Allen, G.O. 1940.
Frenguelli, J. 1939.
Frenguelli, J. 1940.
Gaylarde, P.M. & C.C. Gaylarde 2000.
Guerlesquin, M. 1981a,1981b.
Horn Af Rantzien, H. 1950.
McClintic, A.S. *et al.* 2003.
Morales, E.A. & M.L. Vis 2007.
Patrick, R. 1961.

PHYTOPLANKTON

Acosta, F. 2005.
Acosta, F. & R. Ayala 2003.
Acosta, F. *et al.* 2003.
Ayala, R. 2002
Ayala, R. *et al.* 2003.
Barra, C. *et al.* 1993
Cadima, F.M. 1986, 1990, 1993, 1996, 1998.
Cadima, F.M. & E.A. Morales 1989-92, 1994.
Cadima, F.M. *et al.* 2000.

Carney, H.J. 1984.
Carney, H.J. *et al*. 1987.
Castro, M.M. 2002.
Colque, J.M. 2003.
Couté, A. & A. Iltis 1988
Couté, A. & Y. Thérézien 1985, 1994.
Dalence, S. 1998.
Fontúrbel, R.F. 2006.
Gutiérrez, V.M. 1999.
Gutiérrez, M. & F.M. Cadima 2004.
Iltis, A. 1984.
Iltis, A. & A. Couté 1984.
Justiniano, M.A. 1999.
Lazzaro, X. 1981, 1985.
Liberman, M. & C. Miranda 1987.
López, L.F. 2003.
Morales, E.A. 1993.
Morales, E.A. & F.R. Trainor 1996.
Rejas, D. *et al*. 2005.
Reyssac, J. & N.T. Dao 1977.
Richerson, P.J. & H.J. Carney 1988.
Richerson, P.J. *et al.* 1977, 1991, 1992.
Servant-Vildary, S. 1992.
Tell, G. 1998.
Thérézien, Y. 1985, 1986a, 1986b, 1987, 1989, 1991, 1994.
Theriot, E. *et al.* 1985.
Tutin, T.G. 1940.
Villafañe *et al.* 1992.

SEDIMENTED
Baker, P.A. *et al*. 2003.
Frenguelli, J. 1929.
Fröhlich, F. & S. Servant-Vildary 1989
Miskane, N. 1992, 1997.
Pierre, J-F. 1987, 1990.
Pierre, J-F. & D. Wirrmann 1986.
Rigsby, C.A. *et al.* 2005.
Roux, M. *et al.* 1987, 1991.
Seltzer, G.O. *et al.* 2002.
Servant, M. *et al.* 1995.
Servant-Vildary, S. 1978a, 1978b, 1982, 1983a, 1983b, 1986.
Servant-Vildary, S. & M. Blanco 1984.
Servant-Vildary, S. & M. Roux 1990a, 1990b, 1993.
Servant-Vildary, S. *et al*. 2001.
Sylvestre, F.M. 1997, 2002.
Sylvestre, F.M. *et al.* 2001.
Sylvestre, F. *et al.* 1996, 1998, 1999a, 1999b.
Tapia, P.M. *et al.* 2003.
Vajda-Santivanez, V. 1999.

TYCHOPLANKTON
Cadima, F.M. 1988,1992.
Cadima, F.M. & E.A. Morales 1992.
Cadima, F.M. *et al*. 1994.

MIXED
Barra, C. *et al.* 1990.
Borge, O. 1906.
Britton, E.G. 1896.
Cadima, F.M. *et al.* 2006.
Dejoux, C. & A. Iltis 1991, 1992.
Edwards, D. *et al*. 2001.
Ehrenberg, C.G. 1854a, 1854b.
Harikawa, K. *et al.* 1982.
Iltis, A. 1991a, 1991b, 1991c.
Navarro, G. & M. Maldonado 2004.
Tempere, J. & H. Peragallo 1889-95, 1907-15.
Widmer, C. *et al*. 1975.

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